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A1 **PATENT APPLICATION**

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(54) **Process of Fabricating Objects in Synthetic Resin**

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The present invention relates to a new process of fabricating objects in synthetic resin.

According to conventional molding processes, hollow objects are fabricated by blow molding, or by a joining operation whereby two or more molded parts are assembled together. Both operations are costly and imposed certain limitations on the shapes of the products obtained. Further, there is a known process of injection molding that produces molded foam parts. Injection molding is effective for making objects of complicated shape, but it does not serve to produce molded parts with smooth skin if a synthetic foam resin is used. Further, the molded parts are generally removed from a mold after the injected resin has cooled. However, the cooling time is longer, the thicker the cross section of the molded part.

The invention contemplates a new process of fabricating objects that overcomes all the disadvantages of the conventional process mentioned above.

The process according to the invention consists in injecting a molten resin into a mold cavity and forcing a mass of fluid into such cavity under pressure, so that it is enclosed by the resin.

In the accompanying drawing, given solely by way of example:

Fig. 1 is a diagrammatic sectional view of a mold for operating the process according to the invention.

Figs. 2 and 3 are sectional views showing hollow molded parts fabricated by the process according to the invention.

Fig. 4 is a sectional view of another modified mold that may be used in the process according to the invention.

Fig. 5 is a sectional view showing a molded part fabricated using the mold shown in Fig. 4.

Figs. 6A to 6C are diagrams illustrating a process of fabrication of a foam product by the process according to the invention.

Figs. 7A to 7C are diagrams illustrating another process of preparation of a foam product by the process according to the invention.

Figs. 8A to 8D are diagrams illustrating yet another process of fabricating a foam product by the process according to the invention.

Fig. 9 is a sectional view illustrating another modified mold used in the process according to the invention; and,

Figs. 10A to 10D are diagrams illustrating a process of fabricating an object having a thick cross section by the process according to the invention.

Referring to Fig. 1, we see an injection cylinder 1 of an injection molding machine (not shown) of a type well known in the art. In the cylinder 1 is arranged a screw 2 to plasticize and inject a synthetic molding resin. The screw 2 may be driven rotationally or otherwise by a means not shown.

The mouth 3 of the cylinder 1 is connected to the entrance of a mold 4 in a suitable manner well known in the art. The interior of the cylinder 1 communicates with the cavity 5 of the mold by way of a passage 6 in the mouth 3 and a sprue 7 of the mold 4. The cavity 5 is formed by a fixed portion 8 and by a movable portion 9 of the mold.

To carry out the process according to the invention, a device 10 for injection of a fluid is placed at the exit of the injection cylinder 1. The fluid injection device 10 has an outlet 11 opening into the passage 6 in the mouth 3, permitting a fluid to be introduced into the cavity 5 by way of the sprue 7 of the mold 4. The outlet 11 is connected to a chamber 12 of a cylinder 13 under pressure of a fluid by way of a conduit 14 and a control valve 18. A piston 15 is mounted sliding in the cylinder 13. Said piston can apply pressure to a fluid supplied to the chamber 12 from any source by way of a conduit 16 having a valve 17. When the piston 15 moves to the left as shown in Fig. 1, the fluid in the chamber 12 is subjected to pressure by the piston 15 and enters the cavity 5 by way of the conduit 14, the fluid injection device 10 and the sprue 7.

The synthetic resin to be molded is plasticized by means of the screw 2 in the injection cylinder 1 and injected into the cavity 5 by way of the mouth 3 and the sprue 7 in a quantity smaller than the volume of the cavity 5, this injection being performed under the pressure exerted by the screw 2. Then a fluid under pressure is passed through the outlet 11 of the fluid injection device 10 into the cavity 5 so as to form a hollow portion 20 in the resin 21 injected into the cavity 5, as illustrated in Fig. 2. If more resin is injected into the cavity 5, molded parts 21A may be obtained whose hollow portion 20A is shaped as shown in Fig. 3.

The fluid may be forced into the cavity 5 at the same time as the resin is injected thereinto. In that case, breakage of the layer of resin in the mold cavity due to the shapes of the molded parts to be fabricated can be prevented. This seems to be because the fluid is forced into the cavity while surrounded by the resin, so that the hollow portion can readily be shaped in the molded parts inside the cavity.

When the fluid breaks the resin layer of the cavity even when the procedure indicated above is followed, so that reproducible and satisfactory results are not obtainable, it is better to place the mold cavity under pressure beforehand with the aid of a gas under pressure, before injecting the resin to be molded.

Fig. 4 shows another mold that may be used to obtain satisfactory molded parts without pressurizing the mold cavity beforehand. This mold comprises a fixed portion 30 and first and second movable portions 31 and 32. The fixed portion 30 and the first movable portion 31 form a main channel 33 between them, with a sprue 34 and a secondary channel 35 at their ends. The channel 35 communicates with a cavity 36 of the mold consisting of the first and second portions 31 and 32. This cavity comprises a passage 37 communicating with the atmosphere by way of a valve 38.

Fig. 5 shows a product 39 molded with the mold illustrated in Fig. 4. When a fluid under pressure is forced into the cavity 36, it passes through the injected resin and escapes from the cavity to the atmosphere by way of the passage 37. As a result, a satisfactory reproducibility of the shape may be obtained, and passages 40 of complicated shape can be obtained in the molded parts. Also, the cooling of the molded parts may be accomplished in the passages 40 by continuing to supply fluid to the cavity.

When it is desired to fabricate molded parts of greater thickness, the volume of the mold cavity is enlarged by moving the movable portion, for example the portion 9 in Fig. 1, while at the same time forcing the fluid into the cavity. Further, when the cavity is of a lesser thickness during injection of the resin, enlargement of the cavity is possible in order to obtain molded parts having extremely fine and extremely uniform layers.

The expression 'synthetic resin' is understood to mean any thermoplastic resinous materials commonly used in the art. However, any suitable thermosetting resinous materials may be used. Also, various additives may be added to the said resinous materials.

The expression 'fluid' is understood to mean a liquid or gaseous mass. The gaseous mass may be air, preferably gaseous nitrogen, carbon dioxide, etc. The liquid mass may be water, but any suitable liquid that will not damage the resin to be molded may be employed. Preferably, the liquid is heated beforehand to somewhere near the temperature of the plasticized resin, when forced into the cavity.

According to the invention, use may be made of a foamable resin to obtain molded foam parts having smoother skins than those of molded parts fabricated according to the prior art. Referring again to Fig. 1, a mass of gas is forced into the cavity 5 by way of the mouth 3 and the sprue 7 after or during injection of the foamable resin, to form a hollow portion in the latter. Then the gas is expelled from the cavity 5 in a manner well known in the art when the outer surface layer of the injected resin hardens. Consequently, the foamable resin expands inward to form molded parts having an outer non-foam layer and an inner foam layer surrounded by the outer layer. This non-foam outer layer has a smoother skin because its mass per unit volume is greater than that of molded parts fabricated according to the prior art. A bubble mark at the surface of molded parts may be avoided by placing the cavity under pressure with a gas prior to the stage of injection of the foamable resin.

The resin may be injected into the cavity 5 in such manner that said resin 50 is surrounded by a non-foamable resin 51, as illustrated in Fig. 6A. When a mass of gas is forced into the cavity 5, these resins, as illustrated in Fig. 6B, are pressed against the walls of the mold, forming a hollow portion 52. When the gas is evacuated from the cavity after the layer of non-foamable resin has hardened, at least in its outer surface, the layer 50 of foamable resin, as shown in Fig. 6C, expands to become a cellular body 50A filling the hollow portion 52.

Figs. 7A to 7C illustrate another process of fabrication of foam parts according to the invention. A foamable resin is made to expand once it has been injected in the cavity; then a mass of gas is forced into the cavity (see Figs. 7A and 7B). When the gas is evacuated from the cavity, an inner layer of resin again expands to form an object having a surface layer 53 of greater density and a cellular body 54 surrounded by the surface layer 53.

In yet another process of fabrication of molded foam parts, illustrated in Figs. 8A to 8D, a cavity 55 is capable of being enlarged under the action of the injection pressure of a foamable resin. When the molten resin 56 is injected into the cavity 55, the later is enlarged as shown in Fig. 8B. Then upon forcing in gas, the cavity 55 enlarges to its normal size, while the resin is pressed against the walls of the cavity, forming a hollow portion 57 inside (see Fig. 8C). Then the gas is evacuated from the cavity, so that the inner layer of resin begins to expand and becomes an inner cellular body surrounded by a surface layer having a higher density, as illustrated in Fig. 8D.

Fig. 9 illustrates another mold for operating the process according to the invention. The mold 60 itself comprises a first portion 61 having a sprue 62, a second portion 63 having a secondary passage 64, and a third portion 65 movable relative to the second portion 63. The first and second portions 61 and 63 form a main passage 66 between them, communicating at its opposed end with the sprue 62 and the secondary passage 64, respectively. The second and third portions 63 and 65 form a mold cavity 67 between them, communicating at one end with the secondary passage 64, while comprising a passage 68 for evacuation of the gas at the other end.

The first portion 61 is provided with a feed passage 69 connected to the main passage 66. The outlet of this feed passage may be opened or closed selectively by means of a valve 70 with piston 71 slidingly mounted in a cylinder 72. The piston 71 is intended to receive on its two sides, a pressure admitted through either of the openings 73 and 74.

The passage 69 is likewise connected to a three-way valve 75 by way of a conduit 76. The valve 75 serves to establish communication between the passage 69 and an entrance 77 that may be connected to any suitable source of pressure (not shown), or with another entrance 78 that may be connected to any source of cooling (not shown).

The molten resin 80, which may be plasticized in any injection molding machine, not shown, is injected into the cavity 67 of the mold by way of the sprue 62, the main passage 66 and the secondary passage 64 in a quantity smaller than the volume of the cavity (see Fig. 10A). The valve 70 is then opened, and gas or liquid under pressure is passed into the cavity 67 by way of the main passage 66 and the secondary passage 64, the three-way valve 75 being then in the position illustrated in Fig. 9. The gas forced through the injected resin 80 is evacuated to the atmosphere by way of the passage 68, forming a hollow portion 81 in the resin, as illustrated in Fig. 10B. Then, the three-way valve 75 is turned so as to establish communication between the passage 69 and the entrance 78, so that a coolant, such as water, is passed into the hollow portion 81, so as to cool the resin 80. At the end of a given period of time, the three-way valve 75 is actuated again to establish communication between the passage 69 and the entrance 77. Gas is passed into the hollow resin portion 81 located in the cavity 67 so as to reject the coolant and evacuate the hollow portion 81, as shown in Fig. 10D.

The process illustrated in Figs. 10A to 10D is effective in shortening the cooling time of a molded part, because the latter is cooled likewise at its inner wall.

The following examples will illustrate the invention.

Example 1

A thermoplastic resin is molded to a product taking the shape of a disk 150 mm in diameter and 7 mm in thickness, using the mold shown in Fig. 1. The thermoplastic resin used is polystyrene, plasticized at 200°C and injected into the mold cavity in a quantity of 80 g. Then gaseous nitrogen is passed into the mold cavity at a pressure of 150 kg/cm^2. When the resin has cooled and hardened in the cavity, molded parts are obtained having a hollow portion, as illustrated in Fig. 2. When the plasticized resin is further injected into the mold cavity in a quantity of about 20 g after the gaseous nitrogen has been forced in, then, after cooling for hardening, hollow molded parts as illustrated in Fig. 3 are obtained.

Example 2

In the mold shown in Fig. 1, molten polystyrene is injected, the mold cavity assuming the shape of a disk 20 cm in diameter and 1 cm in thickness. The injection is done by way of a direct central channel. Then gaseous nitrogen is forced in under a pressure of 50 kg/cm^2 via the same passage. While forcing the gas into the cavity under pressure, a movable portion of the mold is made to move away from one of its fixed portions so that the mold cavity is enlarged and has a thickness of 3 cm. In this way, molded parts having a larger hollow portion and a mean density of 0.4 are obtained.

Example 3

Example 2 is repeated, except that the mold cavity is adjusted to a thickness of 3 cm. Molded parts are obtained having surface layers a little thicker than those of the molded parts obtained in Example 2.

Example 4

Foam products are molded using the mold shown in Fig. 1. To the polystyrene resin, as foaming agent, 6% by weight of n-pentane and 0.2% by weight of azodicarboxylic acid amide are added, plasticizing at 200°C. Then this molten polystyrene resin is injected into the cavity of a mold having the shape of a disk 150 mm in diameter and 10 mm in thickness, through a direct central opening. The mold cavity is established by means of iron mold portions and subjected beforehand to a pressure of 10 kg/cm^2 with air before injecting resin in a quantity of 100 g. Then gaseous nitrogen at a pressure of 80 kg/cm^2 is passed into the cavity to form a hollow molded part. Five seconds later, the gaseous nitrogen is removed from the cavity, so that the foamable resin can expand therein. The foam product obtained has a smooth surface layer and an inner foam body surrounded by the surface layer; its mean density is 0.57. When communication is established between the mold cavity, previously placed under pressure, and a source of depressurization upon evacuation of the gaseous nitrogen, products having smoother surfaces are obtained. Besides, the resin expands more uniformly, using gaseous hydrogen heated to 250°C.

Example 5

Foam products are molded by the process illustrated in Fig. 6. In the mold shown in Fig. 1, a polystyrene resin plasticized at 200°C is injected into the cavity in a quantity of 60 g, then foamable polystyrene is injected, similar to that used in Example 4, in a quantity of 60 g. Then gaseous nitrogen is passed into the mold cavity under a pressure of 80 kg/cm^2 to form a hollow portion in the resin that was injected. Five seconds later, the gaseous nitrogen is removed from the cavity, so that the foamable resin can expand to form molded foam parts. These molded parts consist of foam cores surrounded by smooth surface layers. The mean density is 0.7.

Example 6

In the mold shown in Fig. 1, molded parts are produced in the shape of a disk 150 mm in diameter and 7 mm in thickness. The thermoplastic resin used is polystyrene and the liquid is water heated to 200°C. First the thickness of the mold cavity is adjusted to 5 mm, then it is filled with molten resin. Then heated water is passed into the cavity at a pressure of 150 kg/cm^2. Under the action of the pressure of the water passed in, the thickness of the cavity increases to 7 mm. The molded parts obtained, comprising hollow portions, are cooled in the cavity.

Example 7

In the mold illustrated in Fig. 9, cylindrical objects 20 mm in diameter and 300 mm in length are fabricated. The thermoplastic resin is ABS and the liquid is water heated to 200°C. The plasticized resin is injected into the mold cavity in a quantity representing 70% of the volume of the latter, then the heated water is passed into the cavity 67 of the mold at a pressure of 150 kg/cm^2 by way of the passage 69 and the valve 75. Finally, the hollow molded parts obtained are cooled within the cavity itself.

Example 8

In the mold shown in Fig. 9, cylindrical objects 40 mm in diameter and 300 mm in length are fabricated. The thermoplastic resin used is polystyrene. It is plasticized at 200°C, then injected into the mold cavity in a quantity representing two-thirds of the volume thereof. Then gaseous nitrogen is passed into the mold cavity under a pressure of 100 kg/cm^2 to form a hollow portion in the resin, then cold water is passed into the hollow portion to cool it. Then gaseous nitrogen under pressure is again passed into the cavity to expel the water. According to the invention, the time required to mold a single object is one minute and twenty seconds at a mold temperature of 30°C. By contrast, two minutes and thirty seconds were required according to the prior art.

CLAIMS

1. Process of manufacturing objects in synthetic resin, characterized by consisting in the injection of molten resin into a mold cavity in a quantity smaller than the volume of the cavity and the passing of a mass of fluid under pressure into said cavity, so that said fluid mass is enclosed by the resin.

2. Process according to claim 1, characterized by consisting in the further injection of a certain quantity of molten resin into the mold after having passed fluid thereinto under pressure.

3. Process according to claim 1 or 2, wherein the fluid is a mass of gas and the resin is a foamable synthetic resin, characterized by consisting in causing the gas to exit the mold cavity when the foamable resin injected thereinto has hardened at its outer surface layer.

4. Process according to any of claims 1 to 3, wherein the fluid is a mass of gas and the resin is an inner layer of foamable resin surrounded by an outer layer of non-foamable resin, characterized by consisting in expulsion of the gas from the mold cavity when the outer layer hardens at its surface portion.

5. Process according to any of claims 1 to 4, characterized by consisting in the injection of a mass of coolant into the hollow portion of the resin, created by introduction of the fluid, when the fluid is expelled from the mold cavity.

6. Process according to any of claims 1 to 5, characterized by consisting in placement of the mold cavity under pressure by means of a gas prior to injection of the molten resin.

7. Process according to any of claims 1 to 5, characterized by consisting in enlargement of the volume of the cavity when the fluid is passed thereinto.

8. Process according to claim 3 or 4, characterized by consisting in enlargement of the volume of the cavity after expulsion of the gas.

9. Process according to any of claims 1 to 5, characterized by consisting in heating of the fluid beforehand, before passing it into the mold.

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